The Baseline Stabilization Option for *marccd*

(Excerpted from the *marccd* software manual v. 0.20.0)

Introduction

Baseline stabilization is an optional addition to the *marccd* data collection software.

This software option stabilizes the baseline offset level of each CCD image to a more accurate value than only the analog electronics provide. This feature is important in any type of measurement that requires comparisons between successive data frames that include, for example, subtracting (or adding) two data frames, such as one often must do in small angle scattering experiments. Baseline instability can make it appear that there are slightly more or slightly less X-rays across the entire detector (or readout channel) in a data frame. That is different than the read noise, which has no net effect on the average. A stable baseline is less critical for data analysis in which a background value is calculated by measuring the background around each individual spot on the same data frame (typically done in single crystal crystallography experiments).

The baseline level of a CCD is usually established by measuring an analog voltage of the readout amplifier, and the "zero" level can drift over time due to ambient temperature changes or other electronic instability. The time scale on which the drift occurs is usually greater than about 20 minutes or so; therefore, the marccd software default for recollecting background images is every 20 minutes or once every data segment in a dataset.

Expected baseline stability improvement

Whereas the older MarCCD detectors had a baseline stability that was only good to about ±1-2 ADU, the SX Series and MX Series detectors have improved electronic baseline stability, closer to ±0.5 ADU. When this Baseline Stabilization software option is used, the baseline can be improved much further, with baseline stability as low as about ±0.01 ADU.

CCD overscan

The method of improving the baseline is by an overscan technique. When this option is "on," extra blank pixels are read out from the CCD after each line of the CCD is read out from the serial register. In the *marccd* program memory, a temporary data frame which is larger than the normal data frame is recorded, and the pixels outside the imaging area are used to compute the baseline. These blank pixels do not correspond to any real region of the CCD; they are just a result of telling the readout electronics to readout with no charge present. Therefore they are only the analog baseline plus read noise in each pixel. After calculating the difference between the average of the blank pixels and the target (represented by the parameter `corrected_frame_bias`, typically 10 or 100), that difference is applied to all of the data pixels. The blank pixels are cropped, and a corrected output frame of normal size is created.

The tradeoff for using the baseline stabilization mode, or requesting better and better accuracy, is that there will be a modest increase in readout time. For better accuracy, more extra blank pixels

are required to establish a better baseline, causing the readout time and small calculation overhead to increase. This is because each pixel is subject to read noise. The software allows the user to choose the desired accuracy, to optimize either the frame-to-frame dead time or the baseline stability.

In addition to the statistical accuracy based on averaging a certain number of pixels with noise in them, there are also electronic signals that influence the baseline during the readout, so that the statistical limit is not reached in many cases. The net effect of these inaccuracies limits the baseline stability to approximately ±0.01 ADU.

Using the software: Acquire Single Frame menu and Acquire Dataset menu

The user chooses whether to use the baseline stabilization software or not. In the GUI this feature is represented by a **"Baseline stability" checkbox**.

Note: This checkbox does not appear if there is no valid Baseline Stabilization software license on the computer workstation.

The user must also enter a **target baseline stability value**. This number represents the accuracy to which the program will try to stabilize the baseline, in ADU (analog-to-digital units). The resulting data frame will have a baseline value that is approximately the `corrected_frame_bias`, typically 10 or 100, plus or minus the target baseline stability value. For example, if the user enters 0.1, and the corrected_frame_bias is 10 (i.e. images with no X-rays normally have a baseline around 10 ADU), then a data frame with X-rays will result in a baseline value of approximately 10 ±0.1 ADU (and each individual pixel will also have contributions due to X-rays and read noise).

The accuracy limit of this software feature is about 0.01 ADU, so any target value entered between 0 and 0.01 is automatically converted to the limit, 0.01 ADU. Entering a target value of 0 is equivalent to turning off the baseline stabilization.

Using the software: Remote mode

In remote mode, the following commands are used to turn on and off the baseline stabilization (these commands only function if there is a valid Baseline Stabilization software license):

`get_stability`

> Returns the current target baseline stability value. 0.0 means that the stabilization is turned off. Note that the value may differ from the most recent value entered by using "set_stability" because the number of CCD overscan columns is an integer value.

`set_stability,TARGET`

> Sets the target baseline stability value. Entering TARGET=0.0 turns off the baseline stabilization option.